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COLOR EVALUATION OF CANNED TOMATO JUICE WITH NATURAL AND ARTIFICIAL ILLUMINATION

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Color is one of the most important factors in evaluating the quality of canned tomato juice. This study was undertaken to ascertain whether or not a source of artificial illumination was equal to or better than natural light for judging the color of the finished product. Samples of the processed product were obtained from three different producing areas, New York, Ohio and California. The color of the canned juice was evaluated by comparing it to spinning Munsell discs viewed under natural light and two artificial sources of light. The results of the study show that a source of artificial illumination can be substituted for natural light in the judging of the color of canned tomato juice. Use of this artificial source should increase the accuracy of the color judgment of the inspectors by eliminating the use of uncertain and constantly changing natural daylight.

SUMMARY

Using daylight as standard the judges' scores show better correlation between daylight and light No. 1 than between daylight and light No. 2.

Using the Hunter Color and Color Difference Meter as a reference ("a" and "b") shows the correlation for all 3 light sources and the judges' scores to be about equal.

The judges repeated their first and second scoring of the juice more consistently under light No. 1 than under daylight or light No. 2. Their results under daylight and light No. 2 were about equal.

The judges' scores tended to be 0.7 points higher under light No. 2 than under daylight or light No. 1. This was caused by the spectral distribution of the light coming from No. 2, which had an extremely high proportion of wave lengths at the red end of the spectrum.

This study has indicated that it would be feasible to substitute a source of artificial illumination for natural light in the evaluation of color for canned tomato juice. Of the lights tested, light No. 1 would be the most satisfactory substitute.

A standardized gloss on all Munsell papers is mandatory.

INTRODUCTION

Under the Agricultural Marketing Act of 1946 the U. S. Department of Agriculture is authorized to inspect, certify and identify the class, quality, quantity and condition of agricultural products.

Inspections for quality and condition of processed fruits and vegetables are made in various field offices and processing plants throughout the country by representatives of this Department. One very important quality factor to be evaluated for both fruits and vegetables is color. Despite attempts to perfect objective methods for color measurements of agricultural products, most critical color matching must still be done visually. This inspection work is conducted at all seasons of the year both day and night. Because of these varying working hours and working conditions the quality and intensity of both natural and artificial light vary significantly and make visual evaluation of color difficult if not impossible. Canned tomato juice is one product in which the color is a very important quality factor and the judging of this factor is critical. For accurate work a constant source of light with uniform quality is required.

This study was initiated to ascertain whether or not a source of artificial illumination could be satisfactorily substituted for natural light in judging color of canned tomato juice on the basis of spinning Munsell color discs as outlined in the United States Standards for Grades of Canned Tomato Juice.

EXPERIMENTAL

Color Spinners. The color of canned tomato juices was compared visually under daylight and artificial sources of illumination with spinning Munsell papers and then assigned numerical scores. The United States Standards for Grades of Tomato Juice require that the color of GRADE A Tomato Juice receive a numerical score of 26 to 30 points when it is equal to or better (as much or more red) than the color produced by spinning a combination of the following Munsell colors:

R 65% (5R2.6/13) (Glossy finish)

YR 21% (2.5 YR 5/12) (Glossy finish)

N_1 (Glossy finish)

N_4 (Mat finish)

The color requirements of GRADE C juice provide a numerical score of 23 to 25 points for juice with a color equal to or better (as much or more red) than the color produced by spinning a combination of the following Munsell colors described above:

R 53%; YR 28%; N_1; N_4

The percentages of R and YR are fixed in the above categories, with the remaining percentages being made up of all of either one of the remaining achromatic colors, or any combination of the two.

A new supply of the above papers (Production numbers R-3578, Y-3555, BN1-3622 and N4-3544) was obtained from the Munsell Color Company and 6 spinners approximately 3-3/4 inches in diameter were made from the paper and backed with cardboard. Heretofore the gloss on these papers was not the same from one production number to the next. As a result identically painted papers, with varying degrees of gloss, gave slightly different color impressions. Until this condition could be corrected, uniform color evaluation could not be achieved. Therefore, the manufacturer standardized the gloss of the papers and will maintain this gloss on all subsequent productions. The percentages of the 2 neutral colors may be adjusted, thus permitting the values of the spinners to be varied without theoretically changing the hue, to enable the inspector to more nearly match the varying colors of canned tomato juice encountered in the inspection work. The spinners were assembled as follows:

3 GRADE A spinners

R 65%; YR 21%; N_1 14%

R 65%; YR 21%; N_1 7%; N_4 7%

R 65%; YR 21%; N_4 14%

and 3 GRADE C spinners

R 53%; YR 28%; N_1 19%

R 53%; YR 28%; N_1 9½%; N_4 9½%

R 53%; YR 28%; N_4 19%

They were mounted on vertical shafts of 6 fractional horse power electric moters rheostatically controlled to turn at approximately 2,000 R.P.M.

Illumination. The artificial sources were 2 lights with different filters, both using incandescent lamps at 3,000 degrees Kelvin as source of illumination.* A third natural source of light was also used.

1. The best natural daylight avaiable through north window of the laboratory between the hours of 10 a.m. and 2 p.m. EST was used. No evaluations were made on days on which the sky was overcast or cloudy. Tests were performed only on days when the sun shone brightly with or without a few white clouds. Light meter readings showed this light to have an intensity of 400 to 900 foot candles.

2. The first artificial source of illumination consisted of 4 - 1,500 watt incandescent bulbs each with a curved blue daylight filter and a diffusing glass beneath housed in a metal case equipped with suitable exhaust fans. Four sets of filters were provided with the light having color temperatures of 6,000, 6,500, 7,000 and 7,500 degrees Kelvin. After preliminary investigations the 7,000 degree Kelvin filter was chosen as the one which gave a source of illumination that made evaluation of the tomato juice color the least difficult. This light was suspended 18 inches above the samples to give an intensity about equal to the intensity of the daylight.

3. The second artificial source of illumination consisted of a 500 watt incandescent bulb with a flat circular cobalt glass filter. This filter was measured on a G. E. Recording Spectrophotometer and the color temperature was calculated to be 7,000 degrees Kelvin. This light was suspended 30 inches above the samples to give an intensity about equal to the daylight. The samples, using the artificial light sources, were viewed in an open front booth painted neutral gray with a black curtain for closing off the natural light.

Samples. Representative samples of tomato juice packed in the various parts of the country were obtained from the following sources:

1. Juices of varying qualities packed by the New York State Agricultural Experiment Station, Geneva, New York from tomatoes grown in New York State.

2. Juices of varying qualities packed by the Ohio State Agricultural Experiment Station, Columbus, Ohio, from tomatoes grown in the state of Ohio.

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*Light No. 1 - Furnished by Macbeth Daylighting Corp., Newburg, New York
Light No. 2 - Furnished by Keese Engineering Co., San Francisco, California

3. Juices of varying qualities packed commercially in California from tomatoes grown in that state.

Instrumental Color Measurement. The color values of all samples were read on a Hunter Color and Color Difference Meter standardized against a standard reference tile previously calibrated on the Beckman Spectrophotometer. Reflectance measurements were made on the juice using a viewing cell consisting of a plastic tube 3 inches tall by 2-1/2 inches O. D. cemented to a piece of optically polished glass 4-3/4 x 3-5/8 x 1/4 inches. The Color Difference Meter was used without the glass plate, using the L scale, the plastic block with the 2-1/4 inch circular aperture and the small area illumination (3/8 x 5/8 inch).

The "L" (lightness to darkness), the "a" (green to red) and the "b" (blue to yellow) reflectance readings were taken.

PROCEDURE

The color of the samples was first measured on the Color Difference Meter and then evaluated by the judges. The samples were held in metal containers 3-3/8 inches in diameter and 2-3/8 inches tall with the inside enameled black, and were given to the judges in random order. To expedite the evaluation, the percentages of color in the spinners were fixed as described above. This gave a range of values to include color of the juices used. The sample container was placed beside the spinner (under the light source) with the surface of the can contents on a plane level with the surface of the spinners. The artificial lights illuminated surface of the sample and spinner at an angle of 90 degrees and the judge viewed from approximately a 45 degree angle. The natural source of light came to the sample and spinner at approximately a 45 degree angle and the judge viewed from a 90 degree angle. Of the 7 judges used in this study, 5 were able to make enough readings to give results that have statistical significance. A total of 107 samples of juice were read in duplicate giving a total of 924 readings by the judges under the different lights. The judges viewed the sample and spinner directly or made the observations through a cardboard tube held to the eye. The tube was 12 inches long by 1-1/2 inches in diameter. The end of the tube next to the sample was equally divided by a cross piece 1/2 inch wide. This served to mask out the edges of the sample container and the circumference of the spinning disc. The samples were viewed under 3 light sources in random order. The judges were asked to assign 26 to 30 score points, based on the U. S. Standards for Grades of Canned Tomato Juice to juices that had a color equal to or better (as much or more red) than the 3 GRADE A spinners. The color of the spinners was equivalent to 26 score points. A score of 23 to 25 points was given to juices that were not as red as the GRADE A spinner but equal to or better (as red as) than the GRADE C spinners. The color of these spinners was equal to 23 score points. For juices whose color was not as red as the GRADE C spinner a score of 22 points or lower was assigned.

RECORDING DATA

The data were recorded as follows:

1. Sample number
2. Light sequence
3. Sample sequence
4. Spinner number
5. Light meter value of daylight
6. Score points
7. Color Difference Meter values

RESULTS AND DISCUSSION

The average scores for the color of the samples of tomato juice viewed under daylight, lights No. 1 and No. 2 are shown in Table I:

Table I - Average scores of samples of canned tomato juice for color under 3 types of lights by 7 inspectors, April and May 1952

Inspector	Readings 1/	Average scores of samples under		
		Daylight 2/	Light No. 1 3/	Light No. 2 3/
	Number		- - - Points - - -	
1	160	25.4	26.1	26.8
2	122	25.5	25.4	26.4
3	214	26.3	26.0	26.3
4	214	26.0	26.1	26.5
5	174	25.1	25.4	26.1
6	-	-	-	-
7	20	24.5	25.0	25.2
8	20	25.5	24.7	25.8
All inspectors	924	25.7	25.8	26.4

1/ A total of 107 samples of tomato juice was used in this test. Each inspector scored each sample and then repeated his reading later. Only inspectors 3 and 4 evaluated all samples used in the test.

2/ Only north light on clear days during the middle of the day was used.

3/ Light estimated to be around 7000° Kelvin.

The average scores for daylight (25.7) and the light No. 1 (25.8) were almost identical while the use of the light No. 2 resulted in a score (26.4) approximately 0.7 points higher.

The correlation between the judges' color score under daylight and light No. 1 and daylight and light No. 2 are shown in Table II:

Table II - Correlation between inspectors' score of samples of tomato juice for color under daylight and light No. 1 and daylight and light No. 2, by 5 inspectors, April and May 1952

Inspector	Readings	Correlation between score under daylight and Light No. 1	Correlation between score under daylight and Light No. 2
	Number		
1	160	0.87	0.85
2	122	0.86	0.81
3	214	0.90	0.90
4	214	0.90	0.89
5	174	0.84	0.80
All inspectors 1/	924	0.87	0.84

1/ Includes 20 readings each by inspectors 7 and 8 not shown separately.

The correlation between daylight and light No. 1 (.87) is slightly better than between daylight and light No. 2 (.85), with both correlations being very good.

Other investigators, Robinson (3), Younkin (4, 5, 6) and others have compared the ratio of the Hunter "a" reading and the Hunter "b" reading to the judges' score points in a single correlation. The comparison data for this study are shown in Table III.

Table III - Correlation between inspectors' score for color and a/b ratio from Hunter Color and Color Difference Meter, 5 inspectors, April and May 1952

Inspector	Readings	Correlation between inspectors' score and a/b ratio		
		Daylight	Light No. 1	Light No. 2
	Number			
1	160	0.90	0.91	0.88
2	122	0.77	0.72	0.77
3	214	0.88	0.90	0.89
4	214	0.89	0.90	0.90
5	174	0.76	0.86	0.83
All inspectors 1/	924	0.84	0.86	0.86

1/ Includes 20 readings each by inspectors 7 and 8 not shown separately.

The correlation between daylight reading and the a/b ratio was .84 and between the light No. 1 and light No. 2 reading and the a/b ratio were both .86. Although the artificial light sources gave a slightly better correlation, all results were very satisfactory.

In order to analyze the data further, a multiple correlation between the judges' score under the different illuminates and the separate "a" and "b" readings also was made. Table IV shows this multiple correlation to be very good for all sources of light. The light No. 1 was better than daylight and the light No. 2 was better than either.

Table IV - Relationship between inspectors' score for color of samples of tomato juice under each of 3 types of lights and "a" and "b" readings on Hunter Color and Color Difference Meter, 5 inspectors, April and May 1952

Inspector	Readings	Multiple Correlations Coefficients between inspectors' score and "a" and "b" readings 1/		
		Daylight	Light No. 1	Light No. 2
	Number			
1	160	0.92	0.93	0.90
2	122	0.78	0.73	0.79
3	214	0.89	0.98	0.91
4	214	0.91	0.92	0.93
5	174	0.78	0.87	0.86
All inspectors 2/	924	0.86	0.87	0.88

1/ The relationship described is the general form: score = a + b ("a" reading) + c ("b" reading).

2/ Includes 20 readings each by inspectors 7 and 8 not shown separately.

The first 3 mentioned tables show that judges No. 1, 3 and 4 were able to do a better job of evaluating color than judges 2 and 5. However, even their correlations were quite high and show that all the participants in this study were able to score the color very accurately under the controlled conditions of the test. If field judging could be accomplished with this degree of accuracy it would be very desirable. The average difference in score points between the judges' initial and second readings of all samples ranged from 0.0 to 0.4, with an average difference of between 0.1 and 0.2 score points.

This shows that on the average the judges were able to repeat themselves with a great degree of accuracy. In a few instances, variations of 2 score points by individual judges between first and second readings on identical samples were observed during this experiment.

With all samples the judges were able to evaluate the color equally as well or better under the artificial sources of light than they were able to do under the natural source. From this observation we might conclude that either of the artificial sources could be substituted for natural light. However, there is one other factor that should be considered. Although light No. 2 had a Kelvin reading of 7,000 degrees which was the same as the reading for the light No. 1, the spectral energy distribution (Figure 3) curve for this light was extremely uneven and at 650 mu it rose abruptly and at 660 mu rose to over 100. This extreme abundance of energy in the red end of the spectrum resulted in the up grading of all samples by an average of 0.7 score points. Because of this light No. 2 would not be desirable.

In this study only the best daylight for the 4 hour period at mid-day during the months of April and May was used. The judging was not conducted on cloudy or overcast days. In the field it is necessary to do color work both day and night during all the seasons.

Therefore, the use of a satisfactory artificial source of light would greatly extend the working hours of color judging as well as increase the accuracy and uniformity of the color evaluation.

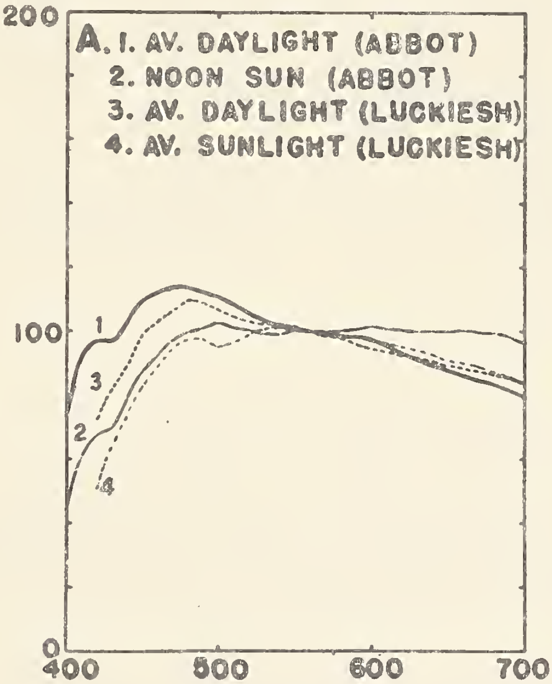
GENERAL COLOR DISCUSSION

Evans (1) states that color is a complex problem which may be divided into 3 parts. The first part consists of a source of light or illumination. The second part consists of the colored surface viewed and the third is the way the eyes and the mind of the viewer react to the above two.

Light Source. Fundamentally light is energy traveling through space in waves, much as those formed in a pool when an object is dropped into the water. The pulsations are of different sizes or wave lengths for the various colors. Since the visible spectrum is continuous one cannot pick a definite point where one color stops and another begins. However, one can assign certain general numerical or wave length regions corresponding to color names. These are as follows:

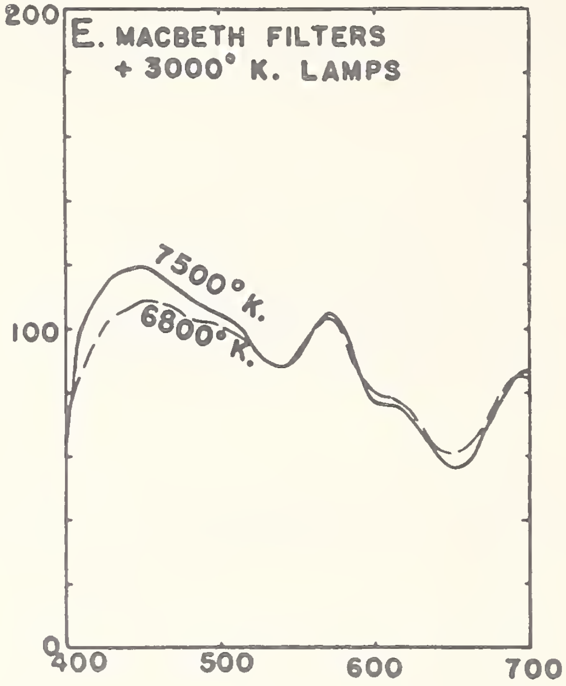
Violet	400 to 450	millimicrons
Blue	450 to 500	"
Green	500 to 570	"
[illegible]	570 to [illegible]	"
Orange	590 to [illegible]	"
Red	[illegible] to 700	"

The following curve shows the relative amounts (percentages) of energy in the different wave length regions over the range for which the eye is sensitive. This will give a thought picture of light showing how much light there is in any one group of wave lengths compared to any other. The curve for average daylight is shown below:



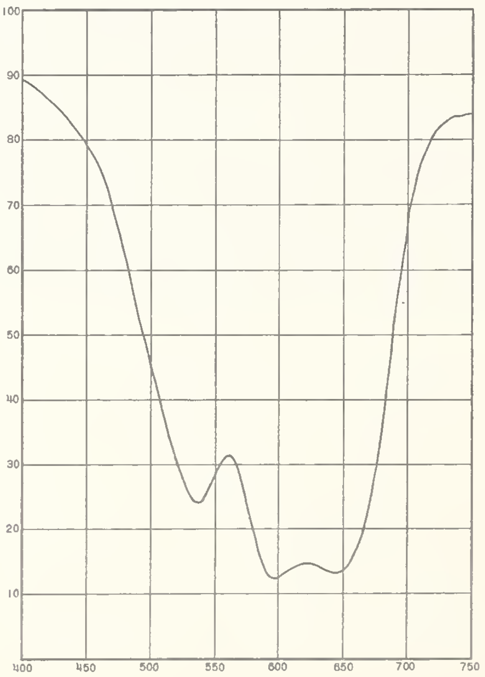
This shows a slight rise in energy at approximately 480 mu which gives the slight bluish white character to daylight. However, the curve remains fairly flat all the way across the wave lengths, which means that daylight gives us illumination that has all wave lengths or colors present in about equal proportions. Artificial illuminants using incandescent lamps for their energy source result in a curve showing a relatively small energy distribution at the lower wave lengths (blues and greens) and a very heavy distribution in the longer wave lengths (yellow and red) which accounts for the yellow character of the light from an incandescent bulb.

The curve for artificial light No. 1 (incandescent lamp with a special curved blue filter) is as follows:



This curve does not exactly duplicate the daylight curve described above, but except for a small rise at 560 mu and a slight depression followed by an increase at 650 - 700 mu it very closely approximates it.

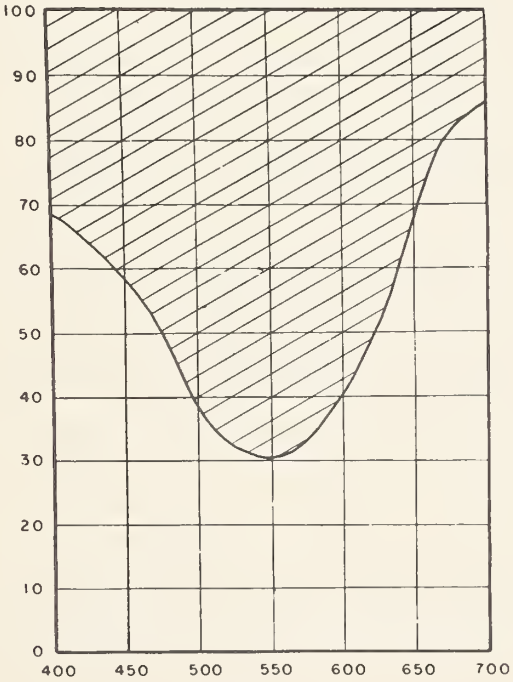
The curve for artificial light No. 2 with a flat blue filter (7,000° Kelvin) and Tungsten Lamp (3,000° Kelvin) is shown:



This curve is much less smooth than the previous curves and has a decided rise at the red end of the spectrum, which means that the red wave lengths have a much larger proportion of energy than the other wave lengths.

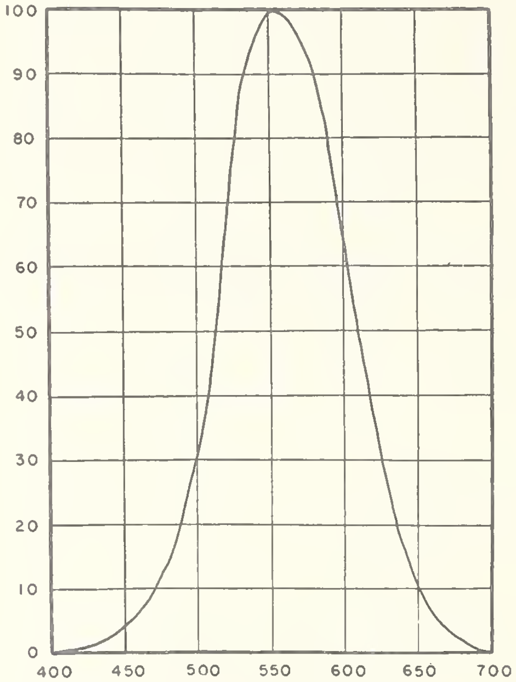
Object Viewed. The second concept involves a colored object. When light falls on the surface of such an object some of the light is absorbed and some of it is reflected. Because of this reflected light, it appears colored to the eye. This absorption and reflection is different in amounts for the different frequencies of light. The net result is that the curve which describes the light leaving the object has a different shape from the one for the light source itself.

A red surface would reflect a higher percentage of light in the short and particularly in the long range of the visible wave lengths, and very little for those which are in the middle range.



The important thing about such a curve is the fact that it describes the surface of the object viewed and not the light which is reflected from it. The spectrophotometric values read tell what percentage of light is reflected at each wave length. If there is an abundance of energy at that wave length in the light source, there will generally be a resultant large amount in the reflected light; conversely if there is no energy at that wave length in the light source, then there will be none reflected no matter what the percent of reflectance may be at that wave length.

Observer. The above 2 curves then - one of the illuminant and the other of the surface - give a representation of what is presented to the human eye. What these mean to the eye might be explained by the following: The photo sensitive part of the eye is a mosaic of receptor cells, rods and cones of the retina. The rods are for night or achromatic vision, yielding perceptions of white, gray and black. The cones are for day or chromatic vision. These cells have at least 3 cone photopigments or photopigment filter combinations which are: short wave absorbing (violet) pigments, middle wave absorbing (green) pigments and long wave absorbing (red) pigments. These cones are individually connected by nerves to the brain. When light rays fall upon the cones that are sensitive to that particular wave length, rapidly repeating nerve impulses carry the color message to the brain. Here we experience our color response or form a mental picture of what the eye has seen. The eye does not see directly the actual energy distribution of the light, but rather it sees only the relative effectiveness of the light on its own receptor system. For example, the eye is most sensitive to the green region of the spectrum. The relative sensitivity of the eye to the different wave lengths is shown by this curve:



Any energy distribution which affects the receptors in the same ratio will be seen as the same color.

From the above we can conclude that in any color problem the way the eyes react is just as important an element as are the quality of the illumination and the nature of the colored surface.

Nickerson (2) discusses color measurement (physically and psychologically) and its application to the grading of agricultural products. Psychologically color has 3 main characteristics which may be described as hue, saturation (or intensity), and brightness (or lightness). Hue is the attribute by which the color is named such as red, green, blue, etc.; saturation is the relative quantity of this hue which is present in the sample; and brightness (or lightness) describes the total amount of light which the sample reflects to the eye. These are the 3 basic visual attributes of color.

Above reference has been made to the quality factor of color for processed fruits and vegetables. This factor is judged by comparing visually the color of a product to a color plate or color chart.

Some of the color charts are: Ridgeway, Maerz and Pauls Dictionary of Color, Otswald, and Munsell. The last one mentioned is used for the evaluation of color of canned tomato juice.

The Munsell system is described as follows:

Hue: The distinctive primary characteristic of any chromatic color, such as red, yellow, green, blue, etc.

Value: The lightness or darkness of any color. In terms of value all colors are described as dark, middle or light.

Synonyms - Brightness, brilliance, or luminosity.

Chroma: Strength or weakness of chromatic color. In terms of chroma, color is described as weak, moderate, or strong.

Synonyms - Saturation, intensity or purity.

ADDENDA

As a result of this study light No. 1 was chosen as the one which would provide the greatest aid in color evaluation of food products.

One large permanent light of this type and several smaller portable lights have been placed in the Department's Washington laboratory and several of the field offices.

This light has been very successfully used since installation, approximately 3 years ago. The inspectors use this light with confidence and are greatly aided by its use in making critical evaluation of color.

ACKNOWLEDGMENT

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